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Research and Application of Heating Network Balance in Central Heating Based on GSAA

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Abstract

The heating balance of central heating network is an important part in the central heating design. This article makes theoretical analysis of the heating for the heating balance control. Through the analysis of central heating networks, the total control solution for heating balance is established. In this article the genetic algorithm is combined with the simulated annealing algorithm to find global optimal solutions, to achieve the balance of heating network and uniform heating. Simulation results indicate that the method has better effect.

Keywords: heating balance; uniform heating; genetic simulated annealing algorithm

1. Introduction

The urban central heating is one of the important measures of the modern city construction. The central heating system is a very complex multivariable control systems in which the heating area is large, influencing factors are more, internal association is strong and nonlinear is serious^[1]. In recent years, central heating technology continues to improve, a number of new technologies and new equipments are adopted, operation and management level has been upgraded. But on the whole, the operation management level of heating network is still different. The operation mode of large flow and small temperature difference is often used. The imbalance status still exists that the room temperature exceeds standard seriously for overheating users and the room temperature can not reach standard for supercool users. The goal to achieve uniform heating of heating networks is not ideal. In order to solve this problem, this article uses a genetic simulated annealing algorithm to find global optimal solutions, to achieve balance of heating network and to obtain uniform heating.

2. The general control scheme

The general control idea is that according to the outdoor temperature and the changes of heating area, the main circulating pump is controlled to adjust the supply amount of heat source and to realize heating on demand. Through adjusting the flowrate of supply and return water in primary pipe network in water heating systems, the heat loads of secondary pipe network are controlled to satisfy the balance of heating pipe network.

Heating according to need means that supply and return water temperature of the primary pipe network changes as the outdoor temperature changes and the users of secondary pipe network are equivalent to the radiator. Under stable conditions, according to that heat supply quantity of system, heat dissipation of radiator and the user's heat consumption are equal, the supply and return water temperature of the secondary pipe network, which will change with the outdoor temperature, can be obtained under steady-state conditions.

$$t_{2g} = t_h + \frac{1}{2}(t'_{2g} + t'_{2h} - 2t_n) \left(\frac{t_n - t_w}{t'_n - t'_w} \right)^{1/(1+\beta)} + \frac{1}{2G_2}(t'_{2g} - t'_{2h}) \left(\frac{t_n - t_w}{t'_n - t'_w} \right) \quad (1)$$

$$t_{2h} = t_h + \frac{1}{2}(t'_{2g} + t'_{2h} - 2t_n) \left(\frac{t_n - t_w}{t'_n - t'_w} \right)^{1/(1+\beta)} - \frac{1}{2G_2}(t'_{2g} - t'_{2h}) \left(\frac{t_n - t_w}{t'_n - t'_w} \right) \quad (2)$$

Where, t_{2g}, t_{2h}, t_n, t_w are respectively the supply and return water temperature of the secondary pipe network, the indoor and outside temperature. G_2 is the relative flowrate to design condition under the operating condition. The signs with an apostrophe represent parameters under design condition. β is the radiator coefficient.

According to the supply and return water temperature of the secondary pipe network obtained from above formula, we can get:

$$t_p = \frac{t_{2g} + t_{2h}}{2} = t_n + \frac{1}{2}(t'_{2g} + t'_{2h} - 2t_n) \left(\frac{t_n - t_w}{t'_n - t'_w} \right)^{1/(1+\beta)} \quad (3)$$

Namely, each supply and return water average temperature have nothing to do with the relative flowrate. Under the same outdoor temperature, each supply and return water average temperature only concern for the indoor temperature.

The supply and return water temperature in primary pipe network can be expressed as formula (4) and (5).

$$t_{1g} = t_{2p} + \left(\frac{t'_{1g} - t'_{1h}}{G_1 \varepsilon} - \frac{t'_{2g} - t'_{2h}}{2G_2} \right) \left(\frac{t_n - t_w}{t'_n - t'_w} \right) \quad (4)$$

$$t_{1h} = t_{2p} + \left[\left(\frac{1}{\varepsilon} - 1 \right) \left(\frac{t'_{1g} - t'_{1h}}{G_1 \varepsilon} - \frac{t'_{2g} - t'_{2h}}{2G_2} \right) \right] \left(\frac{t_n - t_w}{t'_n - t'_w} \right) \quad (5)$$

When quality adjustment is used in secondary pipe network, $G_2 = 1$. After simplification, we have formula (6) and (7) as following:

$$t_{2p} = t_{1g} - \left(\frac{t'_{1g} - t'_{1h}}{G_1 \varepsilon} - \frac{t'_{2g} - t'_{2h}}{2} \right) \left(\frac{t_n - t_w}{t'_n - t'_w} \right) \quad (6)$$

$$t_{2p} = t_{1h} - \left[\left(\frac{1}{\varepsilon} - 1 \right) \left(\frac{t'_{1g} - t'_{1h}}{G_1 \varepsilon} - \frac{t'_{2g} - t'_{2h}}{2} \right) \right] \left(\frac{t_n - t_w}{t'_n - t'_w} \right) \quad (7)$$

$$\varepsilon = \frac{1}{0.5 \frac{W_1}{W_2} + 0.5 + \frac{1}{\omega}} \quad (8)$$

Where, ε is the valid coefficient of heat exchanger, W_1, W_2 are respectively flowrate thermal equivalent of primary and secondary pipe network. $\omega = KF / W_1$, K is the heat transfer coefficient of heat exchanger, F is the heat transfer area of heat exchanger. Substitute formula (6) with ε , after the reorganization, we have formula (9):

$$t_{2p} = \alpha_1 - \alpha_2 \left(\frac{1}{G_1} + \frac{1}{G_2} + \frac{2C_1}{kF} \right) \quad (9)$$

$$\alpha_1 = t_{1g} + \left(\frac{t_{2g} - t_{2h}}{2} \right) \left(\frac{t_n - t_w}{t_n' - t_w'} \right), \quad \alpha_2 = \frac{2(t_n - t_w)(t_{1g} - t_{1h})}{t_n' - t_w'}$$

Where, t_{2p} is, under certain flowrate, the actual average temperature of supply and return water in secondary pipe network when doing site adjustment.

Through above analysis, it can be seen that supply and return water temperature in secondary pipe network can be controlled by adjusting the water flowrate with high temperature in primary pipe network of each heat exchange station. So the genetic simulation annealing algorithm is used to realize the optimal control of high temperature water in primary pipe network. Through adjusting the water flowrate with high temperature in primary pipe network of each heat exchange station, the demand of heating load in secondary pipe network is satisfied to guarantee uniform heating. The quality adjustment is adopted when secondary pipe network is adjusted. The cycle water remains unchanged.^[1-3]

3. Genetic simulated annealing algorithm

1) Genetic algorithm: It is formed through the simulation of biological genetic and evolutionary process in a natural environment, which is an adaptive probabilistic search algorithm for global optimization. By imitating the selection, crossing and mutation mechanisms during the biological genetic and evolutionary process, genetic algorithm completes the adaptive search process for optimal problem solution.^[4]

2) Simulated annealing algorithm: It is a global optimization method which is established based on solid matter's annealing process on physics. It can discover the global minimal point of objective function from the probability significance by the random searching technology.^[5]

3) Genetic simulation annealing algorithm: It is an algorithm that combines the genetic algorithm with the simulation annealing algorithm. Genetic algorithm's partial search ability is poor, however it's overall ability controlling the search process is very strong and it can guide the search process to avoid falling into the partial optimal solution. But the simulation annealing algorithm has less understanding to the condition of entire search space and it is difficult to cause the search constitution to enter the most hopeful search region. So that the operation efficiency of simulation annealing algorithm is not higher. If the genetic algorithm is combined with the simulation annealing algorithm, it will be possible to develop the new global searching algorithm with the fine performance. This is the reason why the genetic simulation annealing algorithm is used.

This paper takes the minimal sum of difference between each supply and return water average temperatures of the secondary pipe network as the goal function value. Each water flowrate with high temperature in the primary pipe network is coded in the binary. The initial population is selected by the roulette method. After the crossing and mutation of population, the fitness function of each individual in

new population is calculated. According to the transition probability p_i which is corresponding to Metropolis criterion of simulation annealing algorithm we can determine whether the transition of individual solution of current new population is accepted. p_i is expressed as following:

$$p_i(i \Rightarrow j) = \begin{cases} 1, f_j \leq f_i \\ \exp(-\frac{f_i - f_j}{t}), f_j > f_i \end{cases} \quad (10)$$

Where f_i and f_j are respectively the values of fitness function of each individual in current and new population.

Figure 1 is the flow chart of Genetic simulated annealing algorithm.

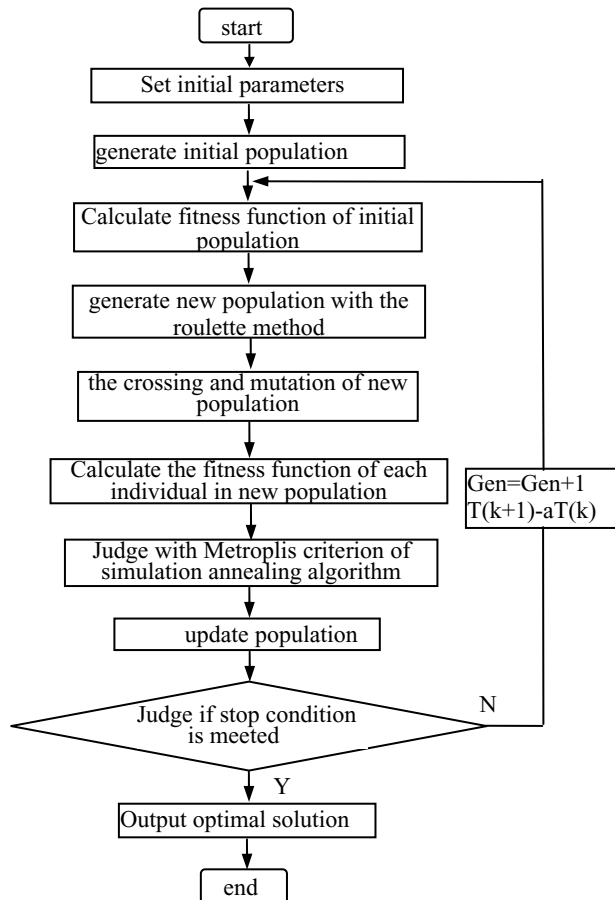


Fig. 1. The flow chart of Genetic simulated annealing algorithm

In the end this method is simulated with MATLAB. The simulation computation has obtained the satisfactory results. Some heating parameters before and after application of GSAA are shown in Table 1.

4 Conclusion

In this article the relationship between each control parameters in heating network is analysed through the formula. The simple control strategy to achieve the balance in heating network is summarized. Selected control algorithm, genetic simulated annealing algorithm, solves the existing problems in heating network, achieves well-distributed heating and saves energy. For the expanding of heat exchanging stations, the balance control can be satisfied by simply updating the program. In the future, the improving of algorithm efficiency is to studied.

Table 1. Some heating parameters before and after application of GSAA

Heating parameter		No.1 heat supply station	No.2 heat supply station	No.3 heat supply station	No.4 heat supply station
Before adjusting	Flowrate of primary pipe network	39	50	93	81
	Average temperature of water in secondary pipe network	50	43	55	45
after adjusting	Flowrate of primary pipe network	36	56	69	102
	Average temperature of water in secondary pipe network	48	47	47	49

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